VI.7 Component Manufacturing and Optimization of Protonic SOFCs

Objectives

- Demonstrate p-SOFC performance of ≥125 mW/cm^2 at 600°C, using scalable manufacturing approaches and improved cell electrodes.
- Demonstrate enhanced cell electrode performance through compositional and microstructural tailoring. Demonstrate (cathode + anode) contributions of <0.5 Ω-cm^2 to cell area specific resistance (ASR) at 600°C.
- Establish tape casting and sintering routes to produce conventional electrolyte components at the button cell and 10 x 10 cm cell size. Minimize cell membrane thickness, with a target of ASR of <1.0 Ω-cm^2.
- Produce of Zn-modified BYZ $Ba(Zr_{1-X}Y_X)O_{3-\delta}$ electrolyte powders at the 600 g batch size, using scalable preparation routes, and demonstrate that these powders in tape cast forms can be sintered to densities of more than 95% ρ_{th} at temperatures of less than 1,400°C.

Accomplishments

- Demonstrated solid state synthesis route as a promising route for production of the proton conducting electrolyte material.
- Densified $BaZr_{0.85}Y_{0.15}O_3$ with ZnO doping (BYZ-Zn) material to 94% theoretical density at 1,550°C.

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Introduction

Protonic solid oxide fuel cells (p-SOFCs) offer unique characteristics compared to competing technologies. In a p-SOFC, protons diffuse from the anode to the cathode through a thin membrane layer, generating power from the electrochemical reaction. P-SOFCs are characterized by their potential for high fuel utilization without steam diffusion limitation, and their intermediate operating temperatures (450-600°C). P-SOFCs avoid steam formation at the anode (experienced by SOFCs), maintaining high fuel concentration over the anode, allowing high fuel utilization and high-efficiency operation. The cells operate at temperatures that increase the reaction kinetics compared to PEM fuel cells, but are low enough to offer the potential for metal interconnects without corrosion. If operating temperatures can be kept at the lower end of this range (using thin membranes and efficient electrodes) conventional high temperature seals may become practicable, avoiding a design issue of SOFC systems.

To date, p-SOFC development has been hampered by processing difficulties associated with ceramic proton-conductors. In this project, NexTech and Caltech will collaboratively advance the materials science and manufacturing technology for ceramic p-SOFCs. Using materials processing strategies for $Ba(Zr_{0.8}Y_{0.2})O_3$ identified by Caltech, NexTech will fabricate its thin-membrane electrolyte-supported cells using proprietary designs well suited to the BYZ material set. This demonstration will require the transition of demonstrated laboratory processes to commercially viable approaches. Caltech will assist this transition and use the resultant cell platform to optimize p-SOFC electrodes. The successful completion of this project will shift p-SOFC development from electrolyte development to electrode optimization and the large cell demonstration.

Approach

Researchers at Caltech have developed a chemical approach in which a sintering aid is used to enhance grain growth and enable densification at reduced temperatures [1]. From a comprehensive screening of transition metal oxides, it was determined that ZnO enhances sintering without generating deleterious intermediate phases or introducing excessive electronic conductivity.

NexTech has developed cost-effective manufacturing processes for a range of state-of-the-art SOFC cell designs. These efforts have revealed the manufacturing and performance strengths and weaknesses of various cell manufacturing approaches. Based on this experience, NexTech developed target specifications for an optimized solid oxide fuel cell, a planar cell component with a thin (≤50 µm) electrolyte, a 30-50 µm thick anode (to improve fuel oxidation kinetics) and a 30-50 µm thick cathode (to minimize oxygen diffusion limitations). The cell should be mechanically robust and have a dense periphery to simplify sealing.

The cell developed by NexTech offers an excellent demonstration platform for protonic electrolyte and fuel cell research. The principal manufacturing steps for the cell platform are tape casting and co-sintering. The processing routes developed at Caltech have been demonstrated with glycine-nitrate produced powders having surface area values (5-8 m^2/g), ideal for tape casting approaches. In this project, NexTech will tailor this process for scaled-up powder production and validate its utility in tape casting and cell fabrication experiments.

Results

ZnO-doped $BaZr_{0.85}Y_{0.15}O_3$ (BYZ-Zn) material was synthesized by the solid state route, producing powder with 11.4 m^2/gm surface area, reasonable for the tape casting approach. The solid state synthesis route was selected due to its scalability and high throughput.

Figures 1 and 2 show the results of the dilatometry and the sintering study for BYZ-Zn synthesized by the solid state route. The dilatometry data shows that the material starts to sinter around 1,100°C and completes its shrinkage by 1,500°C. The sintering study shows that BYZ-Zn sinters to 94% theoretical density at 1,550°C, confirming that the solid state synthesis is a promising route for production of the BYZ-Zn material.

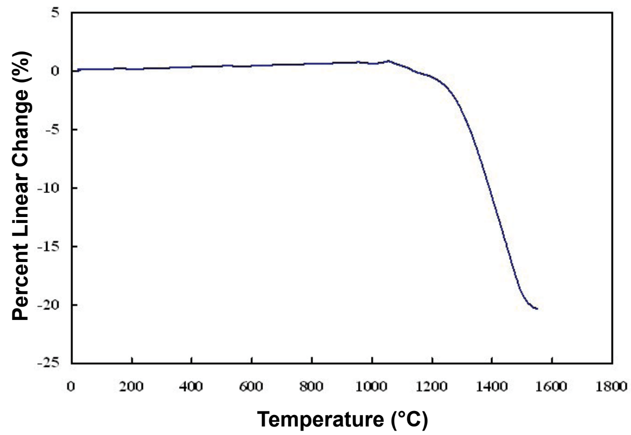

FIGURE 1. Dilatometry Data for BYZ-Zn Synthesized by Solid State Route

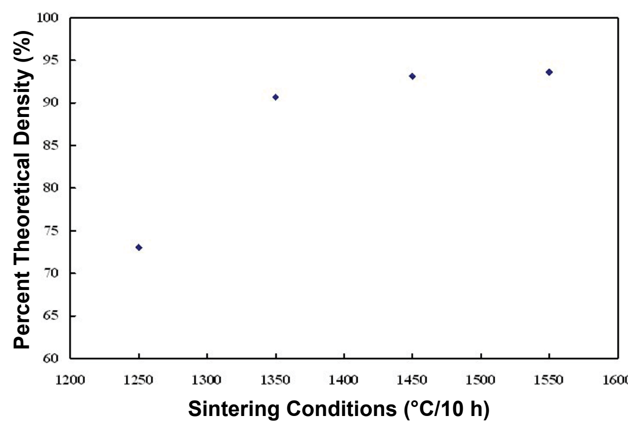

FIGURE 2. Sintering Study for BYZ-Zn Synthesized by Solid State Route

Conclusions and Future Directions

The solid state synthesis route is a promising route for production of the BYZ-Zn material and fabrication of dense electrolyte components at reasonable sintering temperatures. The ongoing work focuses on development of tape casting formulations using the synthesized powder for production of thin electrolyte substrates for fuel cell evaluations.

References

1. Babilo, P., and Haile, S.M., *J. Am. Ceram. Soc.*, 88 (9), 2362-2368 (2005).